

officer making a habit of positioning the device in a particular way. Because some of the positions chosen provided an opportunity for a particular part of the officer's body to be irradiated for a number of years, either by the main beam or by side lobes from it--or even by a lobe projecting to the rear--one particular part of the body of each officer accumulated a lengthy exposure to the near field of this low-power microwave source. It was in this long-exposed part of his body that each affected officer discovered he was developing cancer!

A Senate Subcommittee hearing chaired by Senator Joseph Lieberman of Connecticut was held in Washington, DC, in August, 1992, on this issue. At that hearing it was reported that 164 cases of cancer occurring in chronically exposed parts of officers' bodies --parts that had been irradiated over many years by their traffic radar gun--had been reported to the National Fraternal Order of Police.

This pattern of cancer appearing at irradiated body sites quite close to the opening of the traffic radar gun where the beam was emitted is again consistent with the concept that there is a relatively high risk of cancer in the near field of a low-power source of radio frequency radiation under conditions of chronic (long-term) exposure. However, representatives from industry who attended the hearing categorically denied that the reported cancers had anything to do with the officers' use of traffic radar guns!

It was possible to test this allegation in a scientific manner, but nobody who was scheduled to testify at the hearing had performed such a test! So I did it. The result of my test showed that the statistical *p*-value associated with the null hypothesis --the hypothesis that these cancers had nothing whatever to do with irradiation from the traffic radar gun that the officer used--was less than one in a million!

This is so highly statistically significant as to render it almost impossible that the reported cancers had nothing to do with irradiation from the traffic radar guns! In other words, the reported pattern of cancers in these law enforcement officers almost certainly *was* associated with their previous use of traffic radar guns.

This is the kind of conclusive evidence that has been lacking elsewhere in the electromagnetic spectrum. So we have evidence from kilohertz through gigahertz frequencies that is consistent with the idea that the near field of a low-power radio-frequency or microwave transmitter can be carcinogenic under conditions of chronic exposure--and we have virtually *conclusive* evidence from the gigahertz region of the spectrum! Under these circumstances, it is reasonable to conclude that *the near field of a low-power radio-frequency/microwave source poses a carcinogenic hazard under conditions of chronic (long-term) exposure.*

The antenna of a cellular telephone having the antenna in the handset projects toward the rear of the ear when the cellular phone is in use. Because the reported brain cancers in cellular telephone users occur in the brain just behind the ear on the side of the head on which the cellular telephone is most often used, they occur within the near field of the cellular telephone antenna, or just outside the traditionally defined boundary of the near field. On this basis, we are justified in concluding that the brain cancers that are the subject of lawsuits on behalf of cellular telephone users are indeed the result of exposure to a hazardous electromagnetic field consisting of the near field of the antenna located in these devices, together with the region of space lying immediately outside the boundary of the near field.

Interestingly, I am not the only person to have concluded that cellular phones pose a cancer hazard. Testifying at the 1992 Congressional Subcommittee hearing was William Ross Adey, M.D.; and in his testimony, I was startled to see him warn of a brain cancer epidemic associated with the use of cellular telephones!

This surprised me for several reasons. To begin with, Dr. Adey is a scientist who conducts research; he does not testify in lawsuits. Such research scientists almost *never* make predictions of public health hazards; they normally just report the results of their research, and confine their disputes to arguing with other scientists about the proper scientific interpretation of the results of their experiments. Furthermore, the hearing at which he testified had nothing to do with cellular telephones; it concerned law enforcement officers and traffic radar guns. To issue a warning about cellular telephones at such a hearing was departing from the topic of the hearing.

Dr. Adey's prediction to the Senate Subcommittee of a brain cancer epidemic from the use of cellular telephones was so very unusual as to be unprecedented! The hearing was well-attended by representatives of the various media, and I was interested to see how they would react to this unprecedented warning of a brain cancer epidemic by a prominent research scientist. To my astonishment, the news-hungry media totally ignored this nugget of genuine news and gave it *no coverage at all!*

To summarize, then, there is not yet a scientific consensus that exposure to radio-frequency electromagnetic fields causes cancer in human beings or in other mammals, primarily because of the skepticism of scientists. But the evidence that has accumulated to date so consistently indicates this, that no reasonable person could come to any other conclusion.

I personally am satisfied that chronic exposure to the near field of a low-power radio frequency source is capable of causing cancer in the tissues so exposed. I consider that we are in the early stages of a nationwide--indeed, a worldwide--epidemic of brain cancer caused by the use of those cellular telephones designed with the transmitter in the handset.

How can the public protect itself against this hazard? The obvious answer is: *Don't use any cellular telephone having an antenna protruding from the handset!* If you find yourself in a situation where you *must* use such a telephone, keep the call short. Such a telephone can be kept in a car for emergency use only, provided there are no more than four or five emergencies a year requiring its use. And, of course, keep these telephones out of the hands of children!

The person who needs to use a cellular telephone daily while in the car should get a bag phone. Because the transmitter is in the bag, not in the handset, these cellular telephones can be used freely without fear of a brain cancer hazard. (The bag should be placed several feet away from the user or any passenger.)

I believe it ought to be made illegal to manufacture, import, sell, buy or give away a cellular telephone with the transmitter in the handset (except for research use). Our benevolent federal government, enamoured as it currently is of all things wireless, has not yet deigned to provide the public this degree of protection against brain cancer.

### *Cellular Telephone Towers*

In contrast to the use of cellular telephones themselves, there is no evidence at present of any cancer hazard associated with proximity to the tower-mounted transmitter in a given "cell" that relays calls to and from the cellular telephones in that "cell". Two intrinsic factors determine the cancer hazard from such a transmitter: its frequency and its power. The extrinsic factor that controls the cancer hazard is the distance from the transmitter to a biological target.

Because the fixed transmitter is mounted on a tower high enough to clear local buildings and trees, people normally cannot get close enough to it to get inside or dangerously close to the near field of this transmitter. Keeping people well away from the near field is therefore automatically accomplished, simply as a consequence of the normal manner of use of these transmitters. This is why there is no epidemic of cancer associated with tower-mounted cellular telephone transmitters occurring at this time.

A deliberate strategy for preventing cancer from any radio-frequency transmitter is to determine the spatial extent of the near field around the transmitter, and then to take appropriate measures to prevent people, or body parts, from getting into or close to the near field. Such measures may consist of requiring that the transmitter be mounted a certain minimum distance above the ground, or building roof-top, on a tower or pole; or that a fence or guard be placed around the transmitter so as to enclose the hazardous region of space surrounding the near field.

The exact equation one should use to determine the boundary of the near field depends on the kind of antenna one is dealing with. For most radio-frequency antennas a satisfactory equation for the radius  $r$  is

$$r = \lambda/2\pi = 0.15 \lambda.$$

To make a rough evaluation of the near field of a tower-mounted cellular telephone transmitter, it is necessary to know the frequency of the signal. The frequency is then converted into a wavelength in air.

To convert the frequency  $f$  into a wavelength  $\lambda$  one uses the following formula:

$$\lambda = c/f$$

where  $c$  is the speed of light in air (299,792.5 kilometers/sec.).

EXAMPLE: The tower-mounted cellular telephone transmitter will operate at 900 MHz. What is the wavelength in air? What is the boundary of the near field?

SOLUTION: 900 MHz is 900 megahertz; "mega" means million, so this is  $900 \times 10^6$  Hz. The hertz is measured in units of  $(\text{sec.})^{-1}$ , so  $900 \text{ Mhz} = 9 \times 10^8 (\text{sec.})^{-1}$ .

The speed of light,  $c$ , is usually rounded off for such calculations as this to a value of 300,000 km/sec.

$$\begin{aligned} \text{Thus} \quad \lambda &= \frac{3 \times 10^5 \text{ kilometers } (\text{sec.})^{-1}}{9 \times 10^8 (\text{sec.})^{-1}} \\ &= \frac{1}{3} \times 10^{-3} \text{ kilometers} \\ &= 33.33... \text{ centimeters.} \end{aligned}$$

So the wavelength in air of a 900 MHz signal is about 33 cm, or 333 mm. Since one inch equals 2.54 cm, this wavelength is about 13 inches long, or slightly more than a foot in length.

The near field extends out from the source a distance of about  $0.15 \lambda$ , which is about two inches.

It is common practice to include a *margin of safety* in calculations that are intended to distinguish between what is hazardous and what is safe. No margin of safety has been incorporated in the equation above for the boundary of the near field. Therefore one further step is needed to calculate a "safe" distance from a

transmitter: the radius calculated as the boundary of the near field must be multiplied by a safety factor. The final equation

$$\text{"safe" distance} = (\text{safety factor}) \times r$$

permits calculation of a distance at which the cancer hazard of the electromagnetic radiation is greatly reduced (though it is not zero, which is why quotation marks are put around "safe").

The size of the safety factor is a matter of judgment at present, but for a *low-power* source it is likely to be an integer between 2 and 10. The larger the safety factor, the more confident one can be that the distance calculated does indeed minimize exposure to the hazard associated with the near field of the transmitting source.

If we calculate a "safe" distance from a 900 Mz cellular telephone tower-mounted transmitter, using a safety factor of 10, we get a distance of half a meter: about 20 inches.

It is now clear why the tower-mounted cellular telephone transmitter does not pose a serious cancer hazard to the public in the same way that cellular telephones themselves do. The size of the near field of these transmitters is simply too small, when the transmitter itself is remotely situated.

The same tower that carries a cellular telephone transmitter may carry other transmitters, as well. The size of their near fields may be similarly calculated, based on the frequency of the transmitter. If the frequency of these other transmitters is low enough, the size of their near field may be sufficiently large as to warrant some kind of protective action.

*Caveat: The calculation of "safe" distance recommended here is applicable only to small, low-power sources, not to large sources or to high-power sources.*

*Reference:* Information about calculating the near field of a transmitting source may be found in the following textbook: **Introduction to Health Physics** (2nd or 3rd ed.) by Herman Cember (Professor, Northwestern University, Evanston, IL, USA), published by McGraw-Hill's Health Professions Division.

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